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RESEARCH DEPARTMENT REPORT

ACOUSTIC SCALING:
the design of a large music studio for Manchester

Interim Report

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Research Department, Engineering Division
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Summary

This report describes the application of acoustic scaling techniques to the design of a large music studio. The experiments have shown up various previously unknown factors affecting the efficiency of acoustic modular absorbers particularly in the lower frequency range; a matter which will require further investigation.

The sound quality of the proposed design of studio has been approved by a team of skilled observers.

Issued under the authority of

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION
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1. Introduction

Earlier reports[1,2,3,4,5,6,7] in this series have shown that it is possible, by means of acoustic scaling to simulate to a very substantial extent the sound quality of a studio by means of a model. In view of this success it was decided to use acoustic scaling to help in the design of a large music studio intended for Manchester. It was hoped that in this way a number of possible alternative designs could be assessed subjectively and that some of the usual difficulties encountered in specifying the exact acoustic treatment could be overcome.

Outside acoustic consultants were employed in the overall design of the studio and they made it clear that they were using design techniques which were to some degree unproven and that they were relying considerably on the model technique for checking the results, especially from the subjective aspect.

2. Description of model

The size of the real studio was determined in consultation with the potential users who wanted, when necessary, to employ a wide lay-out for the orchestra. A clear width of 21·6 m (71 ft) was therefore planned with a length of 26 m (85 ft). The height was left to be decided by experiment with the model but a value of 13 to 15 m (45 – 50 ft) was envisaged.

The walls and ceiling had diffusing ribs attached to

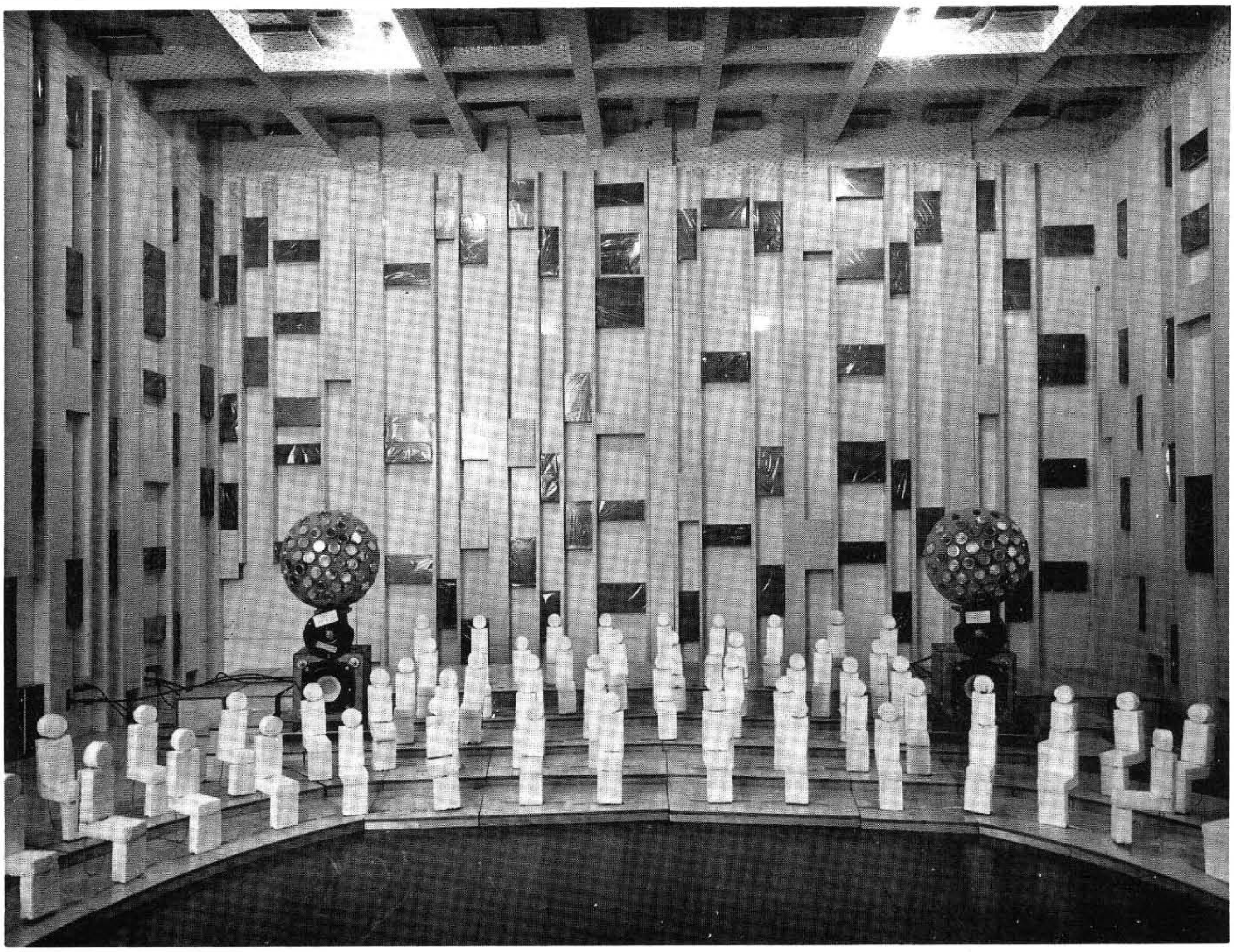

Fig. 1 - Appearance of model

them; in the case of the walls these ribs were spaced at random distances to avoid any risk of the reflected sound being coloured, as might well happen if the spacings were regular.[8] The ceiling was coffered and various size modular absorbers were used to fit in the coffering and between the ribbing of the walls. These absorbers were randomly spaced which helped to maintain adequate diffusion and yield the desired reverberation time.

As with the Maida Vale model,[2] the walls of the model were made of 25 mm (one inch) Laminboard which was coated with three layers of hard polyurethane lacquer. Unlike the Maida Vale model, the ceiling also used the 25 mm Laminboard. Dry air was circulated through holes in the ceiling and walls, corresponding to those to be used for ventilation in the real studio. In choosing the positions for the absorbers care was taken to leave areas free for both ventilation and lighting fittings. The appearance of the model is shown in Fig. 1.

The effects of raising the ceiling in the model of Maida Vale No. 1 studio has been described in a previous report;[6] during those experiments the reverberation time was temporarily raised to 2·2 seconds and it was felt that the sound quality was improved over that with the normal reverberation time of about 1·9 secs. It was originally planned that the value for Manchester should be of the order of 1·5 seconds but as a result of this experiment the design figure was raised to a value of 1·9 seconds for frequencies up to 1 kHz, under the condition of an orchestra of seventy persons present and with no choir or audience, but falling to 1·5 seconds at 8 kHz owing to the inevitable air absorption in a studio of this size.

3. Design of model absorbers

In planning the real studio it was intended to use modular absorbers similar to those employed in existing studios[9] but of differing size and shape. As this change would alter the area of the individual absorbers, the variation in absorption with frequency might well be affected and it was therefore necessary to measure the properties of some real-size modular absorbers in order to know just what properties were needed for the model versions.

A number of real-size absorbers were therefore constructed and their absorption coefficient measured in the large reverberation room at Research Department (Volume 106 m^3). Their properties were found to be satisfactory in the midband and at high frequencies, but there was an unexplained discrepancy below 250 Hz compared with the design data. In addition to the two standard types of absorber the new studio design called for a further type which was intended to absorb down to lower frequencies than before and again difficulty was experienced in getting satisfactory results with this. Although the large reverberation room was not guaranteed for low frequency work, it has always been assumed to be reasonably satisfactory in this regard.

Concurrently, work was proceeding on the model absorbers and with these there was no difficulty in achieving the wideband variety of modular absorber in the model reverberation room,[3] which was made to scaled ISO standards (scaled volume equivalent to 200 m^3), i.e. scaled to a room larger than the full-size room at Kingswood Warren. When the bass absorbers were tested, however, difficulties again arose, some of which were traced to the position of the samples in the reverberation room.

After a number of unsuccessful trials it was decided to use the empty shell of the model studio as the equivalent of an extremely large scaled reverberation room. Under these conditions considerable differences were discovered in the measurements at frequencies below 250 Hz, as compared to those obtained in the model reverberation room, and although the scaled ISO-size room has been assumed to be accurate down to at least 1 kHz (125 Hz in real terms), it appears that it is not so for highly absorbing materials. This matter is to be further investigated with full-size absorbers in the near future. In the meantime the results obtained in the model studio were taken as correct.

Even these results, however, were not straightforward. As described in the previous section, the walls of the studio have diffusing ribs mounted on them and the ceiling has a large amount of coffering. These were both found to affect considerably the absorbent properties of the modules, and separate measurements of modules on both surfaces were found to be necessary. Surprisingly, the frequency range most affected is in the bass. This is unexpected as the diffusing effect of the ribs and coffering is least for long wavelengths and greatest for short ones and thus was expected to change the absorption properties of the modules mainly in the treble range. This, of course, shows up the advantage of modelling as this bass effect was quite unknown and would have required considerable modification of the absorbers in the real studio.

For the model wideband absorbers the perforated fronts were made of a standard brass material with a 25% open-to-closed ratio, i.e. the same as in the full-size absorbers, and with holes and thickness of material also closely scaling the full-size items. For the narrowband and bass absorbers, a rigid p.v.c. sheet was specially perforated for the purpose and although the hole size was larger than scale size demanded, the open/closed ratio was accurate and they functioned correctly. The absorbing material was ¼" felt for the wideband absorber and baize for the narrow band and bass absorbers; in each case the absorbing material was supported on a rigid honeycomb paper material similar in cell size to the scaled cardboard partitions used in full-size versions. The construction is illustrated in Fig. 2.

The scaled absorption coefficients of the various modules are shown in Figs. 3, 4 and 5. In view of the unexpected degree to which the wide-band modules absorb sound at the lower end of the frequency band when in the model studio as opposed to the reverberation room, it was decided that the narrow band absorbers, with an absorption peak centred at 100 Hz, were unnecessary and the design proceeded on the basis of the bass absorbers and the wide-band absorbers only. This result which had not been predicted, should involve a considerable saving in cost.

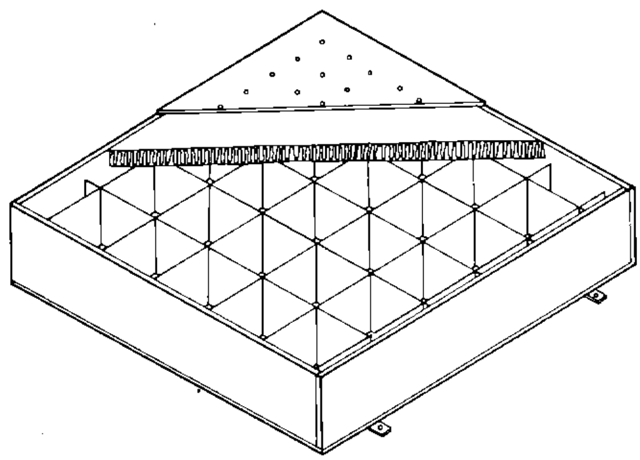

Fig. 2 - Construction of full size modular absorber

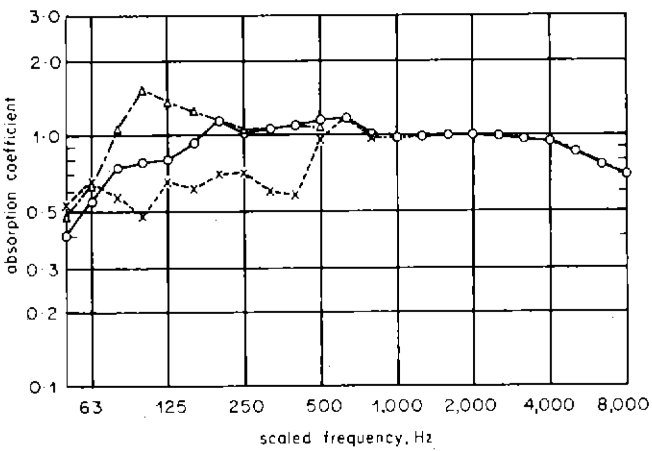

Fig. 3 - Scaled absorption coefficient of wideband modular absorber scattered randomly for various conditions

O——O On walls X----X On ceiling △----△ On floor

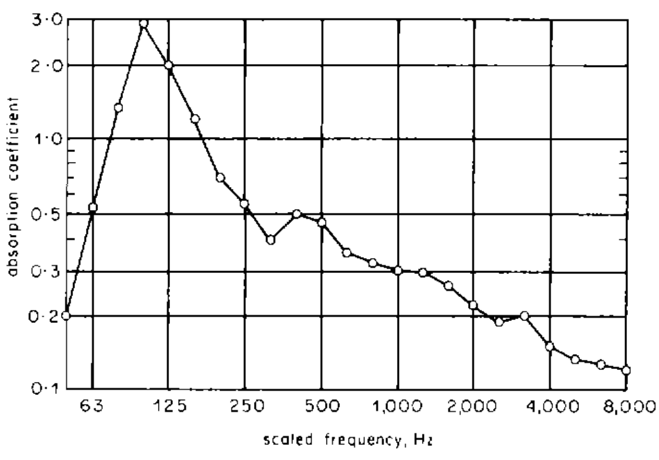

Fig. 4 - Scaled absorption coefficient of narrow band modular absorber scattered randomly

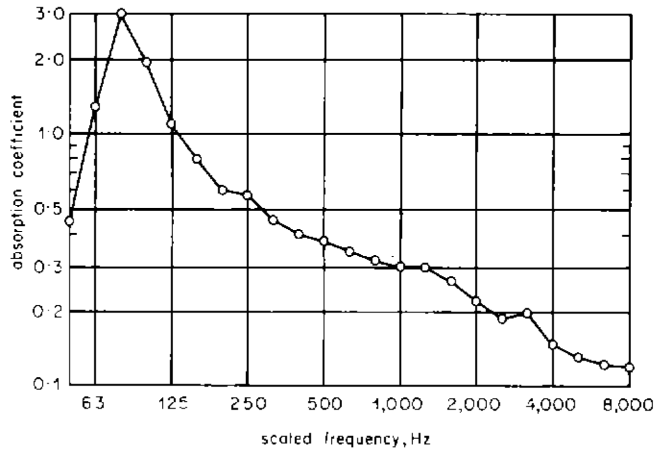

Fig. 5 - Scaled absorption coefficient of bass absorber scattered randomly

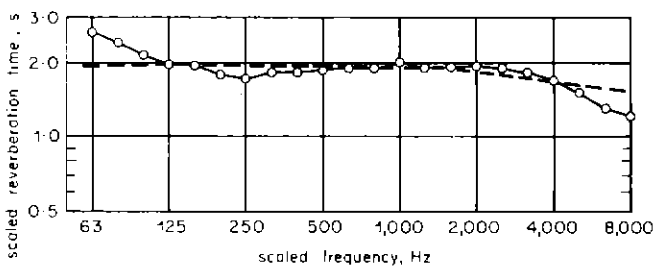

Fig. 6 - Scaled reverberation time on model studio for height of 13·7 m and original acoustic treatment

O——O Measured ------ Design objective

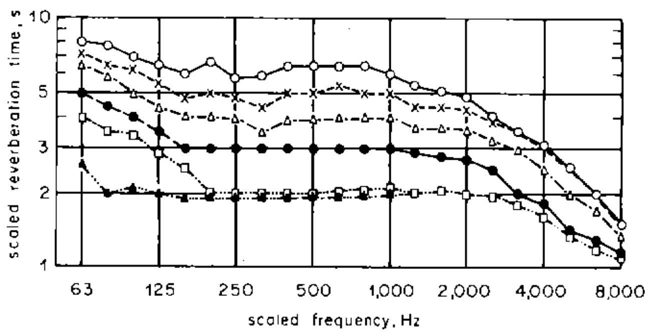

Fig. 7 - Scaled reverberation time in model studio for height of 13·7 m and various degrees of acoustic treatment

O——O No additional treatment
X------X 1/8 No. of wide-band absorbers
△—·—△ 1/4 No. of wide-band absorbers
●——● 1/2 No. of wide-band absorbers
□—··—□ Total complement of wide-band absorbers
▲—···—▲ Total complement of all absorbers

4. Reverberation time

Fig. 6 shows the scaled reverberation time obtained in the model for a height of 13·7 m (45 ft). It will be noted that the planned value has been closely achieved over most of the frequency range, but that the value at high frequencies falls a little below that desired. Air absorption at these frequencies is largely responsible for this, as may be

seen from Fig. 7, which shows the reverberation times for various degrees of treatment of the model.

Recordings using 'dry' programme[1] were made in the model under the conditions of Fig. 6 and listened to by the acoustic consultant and a number of staff intimately concerned with the project. Satisfaction was expressed at the general tonal quality, but it was also thought that a slightly longer reverberation time at high frequencies was desirable.

Experiments were therefore carried out to reduce further the absorption coefficient of the modules in this frequency range. Two alternatives were available: the first was to change the ratio of open to closed area of the perforated front plate of the absorbers to a lower value, the second was to cover the front plate with a very thin non-porous layer. It was not possible in the time available to find a suitable material for the first scheme so the second was chosen. The fronts of the absorbers were covered with a loose layer of Melinex 0·006 mm (0·00025 in.) thick; the absorption coefficient under these conditions is shown in Fig. 8 and it is clear that the use of these absorbers could raise the reverberation time in the desired frequency range.

It was decided that as a first measure only half of the wideband absorbers in the model should be thus covered and the scaled reverberation time obtained in this way is shown in Fig. 9, together with that from Fig. 6. It will be noted that the value measured at 2·5 kHz is now somewhat too high, but that at 8 kHz is now slightly nearer the design value.

Recordings using 'dry' programme were made in the model in this condition and it was decided on a preliminary listening test that the resulting sound quality was a slight improvement over that previously obtained.

In view of this, another experiment was carried out in which all the wideband absorbers were covered with the Melinex. The reverberation curve then obtained is also shown in Fig. 9, and it will be noted that the excess value at 2·5 kHz is now quite definite, whereas the improvement at 8 kHz is still quite small.

Music recordings were made under these conditions and in the judgement of some observers the quality was now slightly too hard and brilliant.

As a result of the sound quality obtained from these three recordings it was decided that, contrary to the original scheme, there was no point in examining the effects of increasing the height of the studio by 2 m (6 ft). Instead attention was turned to a Research Department suggestion that the effects of reducing the height by a similar amount should be investigated for the three conditions of acoustic treatment.

This was done and both recordings and reverberation time measurements were made; the results of the latter are shown in Fig. 10. As expected from previous experience[6] in changing the height of the ceiling in the model of the Maida Vale Studio No. 1, no appreciable effect of this last change in height was obvious in the sound quality.

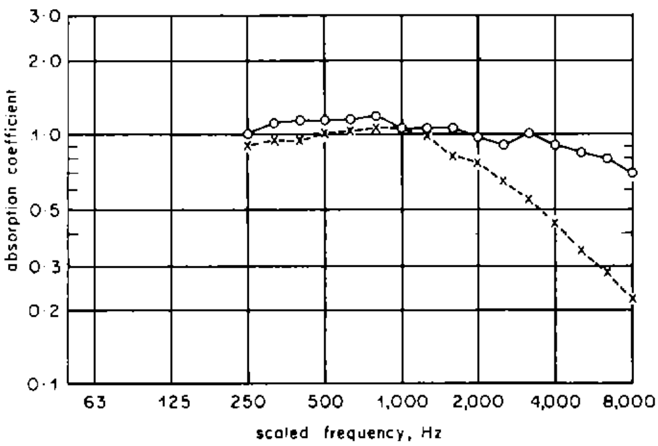

Fig. 8 - Effect on scaled absorption coefficient of wideband absorber of cover of loose 0·006 mm Melinex

O———O Absorption coefficient, normal design
X-----X Absorption coefficient, with Melinex

5. Subjective tests

In order to assess more accurately the subjective effects of the various changes which had been made to the model, it was necessary to make tests employing a large number of observers. A tape was prepared in which each of the con-

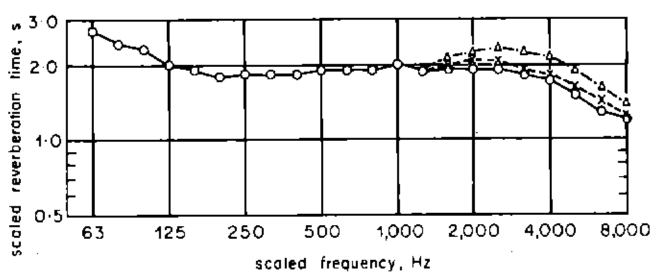

Fig. 9 - Scaled reverberation time in model studio for height of 13·7 m; wideband absorbers bare, 50% and 100% covered with loose 0·006 mm Melinex

O———O All absorbers bare
X-----X 50% wideband absorbers covered with Melinex
Δ—·—Δ 100% wideband absorbers covered with Melinex

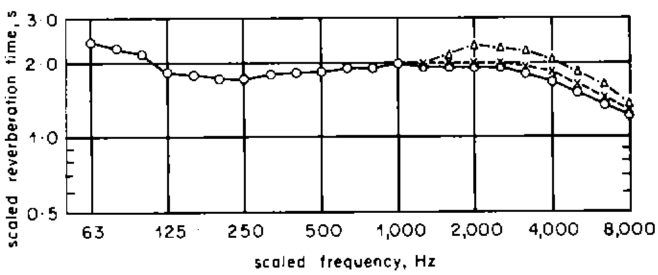

Fig. 10 - Scaled reverberation time in model studio for height of 12·2 m; wideband absorbers bare, 50% and 100% covered with loose 0·006 mm Melinex

O———O All absorbers bare
X-----X 50% wideband absorbers covered with Melinex
Δ—·—Δ 100% wideband absorbers covered with Melinex

TABLE 1

Order of Preference	1		2			3
Rating	0·6	0·6	0·2	0·2	−0·3	−0·5
Condition	14 m 100% Melinex	12 m 100% Melinex	14 m 50% Melinex	14 m No Melinex	12 m No Melinex	12 m 50% Melinex

ditions was compared with that having a height of 13·7 m (45 ft) and with 50% of the absorbers covered with Melinex; this serves as a convenient standard. Each comparison lasted for about five minutes and sections of the Mozart and Malcolm Arnold recordings[1] were used as well as staccato chords. The technique of interlacing the two conditions on an 'ABAB' basis as described earlier[7] was employed together with a test recording in which the two conditions compared were identical to act as a check on the subjectively acuity of the subject.

The team of observers consisted of P.O.A.s and others from London and Manchester, and of Research Department staff; a total of 36 subjects took part in the tests.

Observers commented on the fact that all six conditions presented were very close together in sound quality and all were probably satisfactory. The total variation in mean gradings between conditions was only ±0·5 in a situation which allowed ±5 as the extremes of the subjective scale, thus confirming the comments made. There was no preference for either height which was in accordance with what was expected but there was a slight preference for the 100% Melinex condition.

Table 1 shows the mean overall preferences registered for the whole team. In the case of three items the differences are too small to be statistically significant so that the six conditions can be placed in only three groups as shown. It should again be emphasised that the difference even between the extremes is very small subjectively.

6. Conclusions

The proposed plans for the new Manchester music studio have been successfully modelled. In the process, anomalies in the present method of measuring high absorption coefficients below 250 Hz have been discovered and are to be investigated further. Six possible variations in acoustic conditions of the studio have been measured and assessed and although the differences are very small it is suggested that the condition with maximum high-frequency reverberation should be chosen. There is no preference for the sound quality at either height, so this factor can be decided on other grounds. As a result of these tests it has been suggested by the potential users that the effects of a longer reverberation time be examined.

7. References

1. BURD, A.N. Non-reverberant music for acoustic studies. BBC Research Department Report No. 1969/17.
2. HARWOOD, H.D. *and* BURD, A.N. Acoustic scaling: general outline. BBC Research Department Report No. 1970/13.
3. SPRING, N.F., RANDALL, K.E. *and* SMITH, M.K.E. Acoustic scaling: a one-eighth scale model reverberation room. BBC Research Department Report No. 1971/3.
4. HARWOOD, H.D. et al. Acoustic scaling: an evaluation of the proving experiment. BBC Research Department Report No. 1972/3.
5. HARWOOD, H.D. *and* LANSDOWNE, K.F. Acoustic scaling: instrumentation. BBC Research Department Report No. 1972/34.
6. HARWOOD, H.D. *and* LANSDOWNE, K.F. Acoustic scaling: the effect on acoustic quality of increasing the height of a model studio. BBC Research Department Report No. 1974/12.
7. HARWOOD, H.D. et al. Acoustic scaling: an examination of possible modifications to Maida Vale Studio No. 1. BBC Research Department Report No. 1974/27.
8. BILSEN, F.S. Repetition pitch. *Acustica*, Vol. 17, 1966, p. 295.
9. BURD, A.N. Low frequency sound absorbers. BBC Research Department Report No. 1971/15.

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